An Analysis of Alternative Fish Transportation Strategies

COMPLETION REPORT

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EXECUTIVE SUMMARY

This report examined the potential for an expanded fish transportation program under an assumption of fully operational fish bypass facilities being present at mainstem Snake and Columbia River hydroelectric facilities. The U.S. Army Corps of Engineers FISHPASS model was used for the analysis. Results indicated that additional transportation would be of marginal benefit to any stocks except those entering the pool immediately above the dam being considered. For this reason, Ice Harbor Dam is least attractive for addition of transport. John Day and Lower ?lonumental were the most attractive as preferred locations for transportation facilities.

The effect of variations in turbine mortality was very small when compared to changes in reservoir mortality. For yearling chinook, halving reservoir mortality nearly doubled survival rates while doubling reservoir mortality caused a 75 percent decrease in survival. In contrast, doubling turbine mortality dropped survival rates by 28 percent and halving turbine mortality resulted in an increase of 1.17 times the base case survival rate.

Mortality outside the scope of the study was also considered and its effect on modeling results was discussed. Smolt mortality before reaching the first dam is currently very high (52% for test Dworshak steelhead in 1986) and was not considered in modeling results. Since this mortality must be the same for randomly selected transport groups and fish left to migrate in-river, results of this analysis should not be altered.

Post-transport mortality vs. in-river mortality (so-called "differential mortality") could have substantial bearing on the results of any transport analysis and was not considered in the modeling analysis. For this reason, differential mortality was discussed and hypotheses which could explain the existence of a real or apparent mortality were presented. Given the overriding impact of reservoir mortality and current inability to effectively alter this mortality, transport appears to be worth assessing. Despite the uncertainty involved with the success of transport, a short term commitment to transport (including adequate research) is more viable than the current mixed mode alternative of transport plus in-river passage.

The analysis also examined the effect of variation in parameters used in the FISHPASS model on the predicted survival of salmonids. It was important to determine not only the effect of year-to-year variation in hydrologic conditions but to evaluate the effect of sources of mortality which were not varied in the model but had a high degree of variability in their estimation (turbine and reservoir mortality). Results indicated that variations in flow patterns within the month (day-to-day or week-to-week) did not greatly affect the results but that seasonal shifts in runoff timing (early vs. late) could have substantial impact.

INTRODUCTION

Purpose

The purpose of this report is to evaluate the role of expanded fish transportation in increasing the survival of juvenile anadromous salmonids within the Columbia River Basin using expected 1992 fish passage conditions. This will be accomplished through the use of computer simulation, specifically the U.S. Army Corps of Engineer's (Corps) FISHPASS model (1). Analyses will examine the survival of juvenile fish, both transported and in-river migrants, and evaluate the feasibility of transporting fish from all Federal dams on the mainstem Snake and lower Columbia Rivers. The sensitivity of the model to key parameters which affect fish survival will be evaluated to determine the effect of imprecise data on the results presented. Factors outside the scope of the model, important in the evaluation, will also be discussed.

Background

The construction of four of the current eight mainstem Columbia and Snake River hydroelectric dams, as well as the addition of expanded generating capability at existing dams, was accompanied by a precipitous decline in runs of anadromous salmonids from the Snake River Basin. The decline in fish runs was attributed to a failure of large numbers of juvenile salmon to survive doh'nstream migration through the newly created reservoirs and past the dams. In response to this problem, the Sational Marine Fisheries Service (NMFS) began an investigation of a program to remove fish from the river at headwater dams and transport the fish dohnstream past the killing effects of additional dams and reservoirs. The history of this project is summarized in the "Comprehensive Report of Juvenile Salmonid Transportation" (2).

The success of the transportation program can be measured in two ways. The first is to examine the return rate and contribution to fisheries of transported fish against that of fish migrating in-river or some other base level. This is, of course, the index by which the ultimate success of the program must be measured. However, this measurement is difficult to make accurately; therefore, results are difficult to interpret. The effect of a potential differential ocean survival for transported and non-transported fish must be taken into account and interpreted for this index to have meaning. Traditionally, this means of measurement has been used as a measure of success. Transport has been compared to in-river migration through the use of tagged fish which are allowed to migrate through the reservoir system. The comparison of survival between these groups termed the "transport to control ratio" has been evaluated as the key statistic to judge success of the program (2).

An alternative means of evaluating transport is to assess the change in survival of smolt populations during the downstream migration. This can be measured by the number of fish which survive to below Bonneville Dam, the dam furthest downstream and site of release for transported fish. This measurement is relatively simple to make in the field and can be done with reasonable precision. This is the index which is simulated by the FISHPASS model and the one which will be used in this evaluation. After these results are presented, a discussion of the differences between this and the former index will be made and two hypotheses to explain the substantial differences in results obtained will be presented and discussed.

The following sections will discuss the model used in this effort, the input data, and the affect of variations in selected model input on the results of this analysis.

The Model

The model used for this analysis was FISHPASS, a simulation model, developed by the U.S. Army Corps of Engineers (Corps), NOrth Pacific Division, for use in evaluating alternative juvenile fish passage plans. The model was used as received from the Corps with two exceptions. A coding change was made to allow transportation from every project (Lower Granite to Bonneville) and another to terminate operation of sluiceways at The Dalles and Ice Harbor Dams and simulate the operation of bypass/transportation systems at these projects. The basic input file was data which simulated the 1986 fish passage (spill) plan. This file used 1942 water conditions, which were similar to flows expected for 1986. Specific changes in input, which were made to allow for expanded transportation or bypass, are described in a later section. Fish guidance efficiencies (FGE) were set at a level approximating near term (1992) bypass system improvements and installation (Table 1). These FGE's, obtained from the Corps (3), attempt to simulate levels which can be reasonably achievable in the foreseeable future. Levels of mortality due to reservoir passage, transportation, and project passage were as developed by the Northwest Power Planning Council's Mainstem Passage Advisory Committee (MPAC) and used in the Corps' 1986 spill plan development. Input for each study will be described with the results of specific analyses.

TAELE 1. PROJECTED FISH GUIDANCE EFFICIESCIES AT FEDERAL DAMS ON THE MAINSTEM COLUMBIA AND SNAKE RIVERS (1993 AND AFTER)

DAM	SPECIES OR RACE YEARLISG CHINOOK	SUBYEARLING CHINOOK	STEELHEAD
LOWER GRANITE	0.70	0.40	0.90
LITTLE GOOSE	0.74	0.40	0.80
LOWER MONUMENTAL	0.73	0.40	0.83
ICE HARBOR	0.75	0.40	0.80
MCNARY	0.80	0.52	0.90
JOHN DAY	0.72	0.40	0.86
THE DALLES	0.65	0.40	0.70
EOSNEVILLE FIRST POWERHOCSE	0.76	0.72	0.78
BONNEVILLE 1/ SECOND POWERHOUSE	0.64	0.30	0.60

1/ Operation restricted in studies.

EVALUATION OF THE EFFECT OF INPUT DATA OS RESULTS

From the outset of modeling analysis, it was realized that many of the assumptions concerning sources of, and added measurements of, mortality to smolts were variable and could have dramatic effects on the results produced. For this reason, comparison sensitivity studies were completed to evaluate the impact of substantial changes in some of the variables suspected to have a major impact on any analysis which relies on the FISHPASS model.

Flow Level and Timimg

Monthly average outflow data for water years 1929 through 1967 regulated to 1991 operating conditions (loads and resources) were obtained from the Bonneville Power Administration's (BPA's) Pacific Sorthwest Loads and Resources (White Book) studies (4). Outflows at Lower Granite and at The Dalles were examined to ascertain which flow years could be said to represent early, average and late runoff conditions in years of low, moderate and high spring and summer runoff. First, April through August runoff for each year was compared to average runoff for this period. Years more than twenty percent above or below average runoff were labeled high or low runoff years, respectively. Years where runoff was within five percent of average runoff were labeled average.

April and May runoff values were summed for each year as was June through August. The latter sum was then subtracted from the former. This difference was compared to the average value for each runoff level (low, moderate, high) and a year of extreme value was selected to represent early, average and late runoff. Within in each flow class, years with early, average and late runoff timing were then selected. For the Snake River, 1934, 1930, and 1941 were chosen to represent low flow under early, average, and late runoff conditions respectively. Results of this process are presented in Table 2 for the Snake River and Table 3 of the Columbia River. Appendix tables Al and A2 contain complete listings of the water year data.

Using these flow years, studies were run which compared survival of yearling chinook, subyearling chinook, and steelhead smolts from above Lower Granite Dam to below Bonneville Dam. In this series of studies, no fish were transported, and dam passage was set to 90 percent fish survival, a level achievable without spill at the specified FGE levels.

Total runoff was, of course, a critical element in determining the survival of yearling chinook as was runoff timing. For example, survival under early runoff conditions was better than survival under the next higher flow level with late runoff (Figure 1). Worst survival (8.8 percent) was obtained with low, average timed runoff. This was true even though monthly average flows in the average timed, low runoff year were more than 20 kcfs higher than under early, low runoff year (Table 4). The best survival (29.7 percent) occurred under high flow and average runoff timing.

Table 2--FLOG; TIMING AT LOWER GRANITE - see Appendix Al

for details.

Selected Flow Years

Year	Flow	Timing
1934	Low	Early
1930	Low	Avg
1941	Low	Late
1936	Avg	Early
1954	Avg	Avg
1933	Avg	Late
1952	High	Early
1965	High	Avg
1964	High	Late

Table 3--FLOW TIMING AT THE DALLES - see Appendix A2
for detaiis.

Selected Flow Years

Year	Flow	Timing
1940	Low	Early
1944	Low	Avg
1945	Low	Late
1934	Avg	Early
1960	Avg	Avg
1955	Avg	Late
1951	High	Early
1943	High	Avg
1950	High	Late

Survival of subyearling chinook from Lower Granite to Bonneville (Figure 2) was also both flow and timing dependent. This reflects the model's use of flow dependent survival curves for subyearling chinook at all projects except John Day. The model is set to run in this manner since data exists to indicate that subyearling chinook do not move in a flow dependent manner in the John Day Reservoir, but similar data does not exist for other reservoirs where flow dependence is assumed (5). These subyearling fish generally fared better with average to late runoff than with early runoff. Worst survival occurred with low runoff and average timing (1.5 percent). Best survival was found under high runoff and average timing (14.7 percent). Overall, survival of subyearling fish was substantially lower than that of yearlings and was Likely due to the much poorer guidance efficiency for these fish.

Steelhead survival (31.76 percent on the average) was higher than that of yearling chinook (19.64 percent) or subyearling chinook (7.41 percent). Highest survival occurred under early or average timing of flows with maximum survival (33.2 percent) taking place under high flow and average runoff timing (Figure 3). Lower survival (8.6 percent) came under low flow and average runoff timing.

From the results described above, it appears that care must be taken not to assume that flow level alone will determine smolt survival. Even when two water years have a similar runoff volume, timing of runoff may have a profound effect on smolt survival.

FIGURE 1: SURVIVAL UNDER VARYING WATER CONDITIONS
YEARLING CHINOOK: LOWER GRANITE TO BONNEVILLE

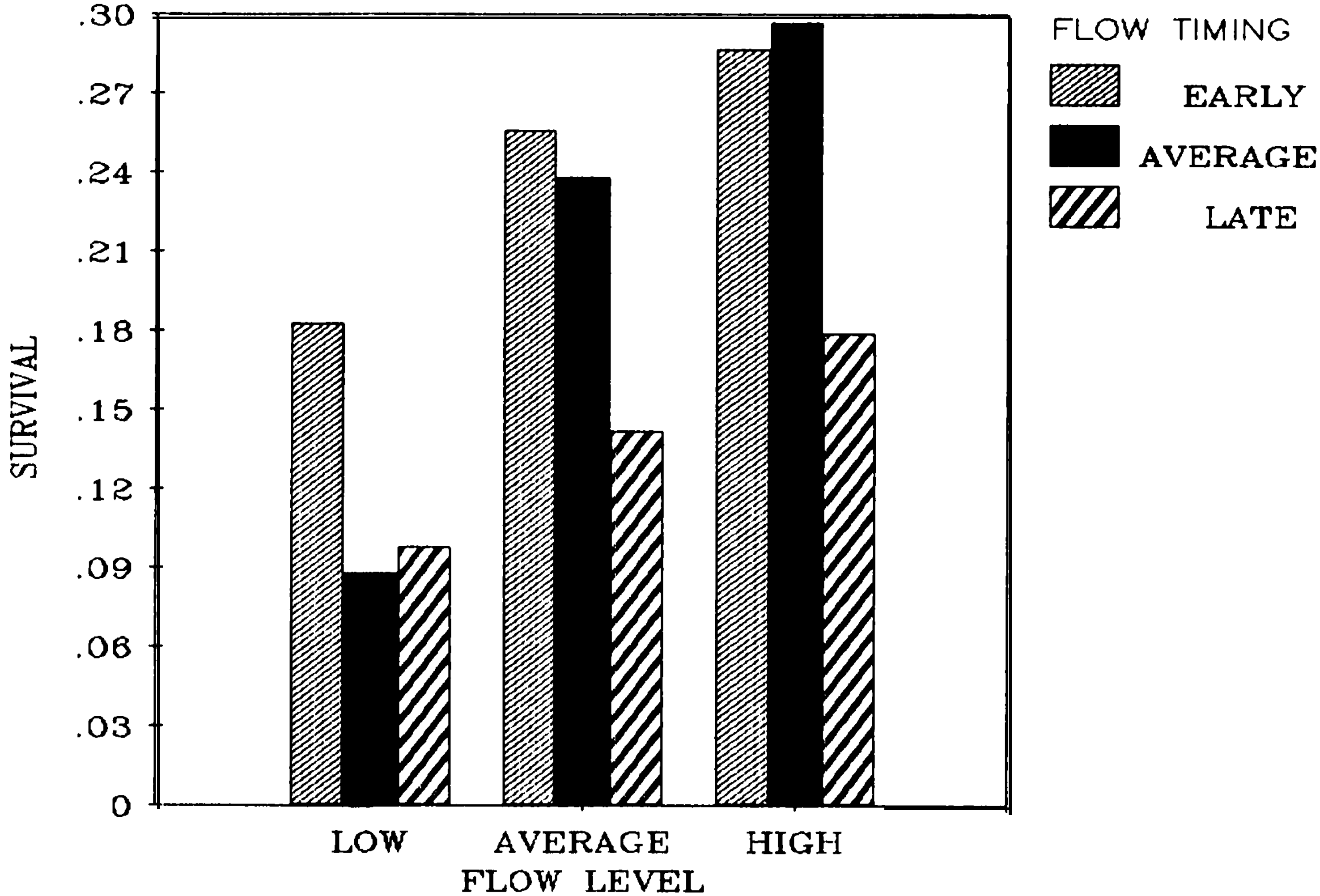


Table 4.-SURVIYAL FROM LOWER GRANITE TO BONNEVILLE DAM UNDER VARYING WATER CONDITIONS

Year	Flow Level	Runoff Timing	Transportation Occurring	Average Monthly Flow	Yearling Chinook Survival to Bonneville Dam	Subyearling Chinook Survival to Bonneville Dam	Steelhead Survival to Bonneville Dam
1934	LOW	Early	NO	198280	0.183	0.019	0.167
1930	LOW	Average	NO	210943	0.088	0.015	0.086
1941	LOW	Late	NO	229038	0.098	0.022	0.116
1936	Average	Early	NO	308394	0.256	0.021	0.244
1954	Average	Average	NO	335239	0.238	0.126	0.287
1933	Average	Late	NO	320268	0.142	0.119	0.183
1952	High	Early	NO	467102	0.287	0.055	0.313
1965	High	Average	NO	482139	0.297	0.147	0.332
1964	High	Late	NO	393972	0.179	0.142	0.23
1934	LOW	Early	Yes	198280	0.819	0.462	0.898
1965	High	Average	Yes	482139	0.831	0.557	0.883

FIGURE 2: SURVIVAL UNDER VARYING WATER CONDITIONS
SUBYEARLING CHINOOK: LOWER GRANITE TO BONNEVILLE

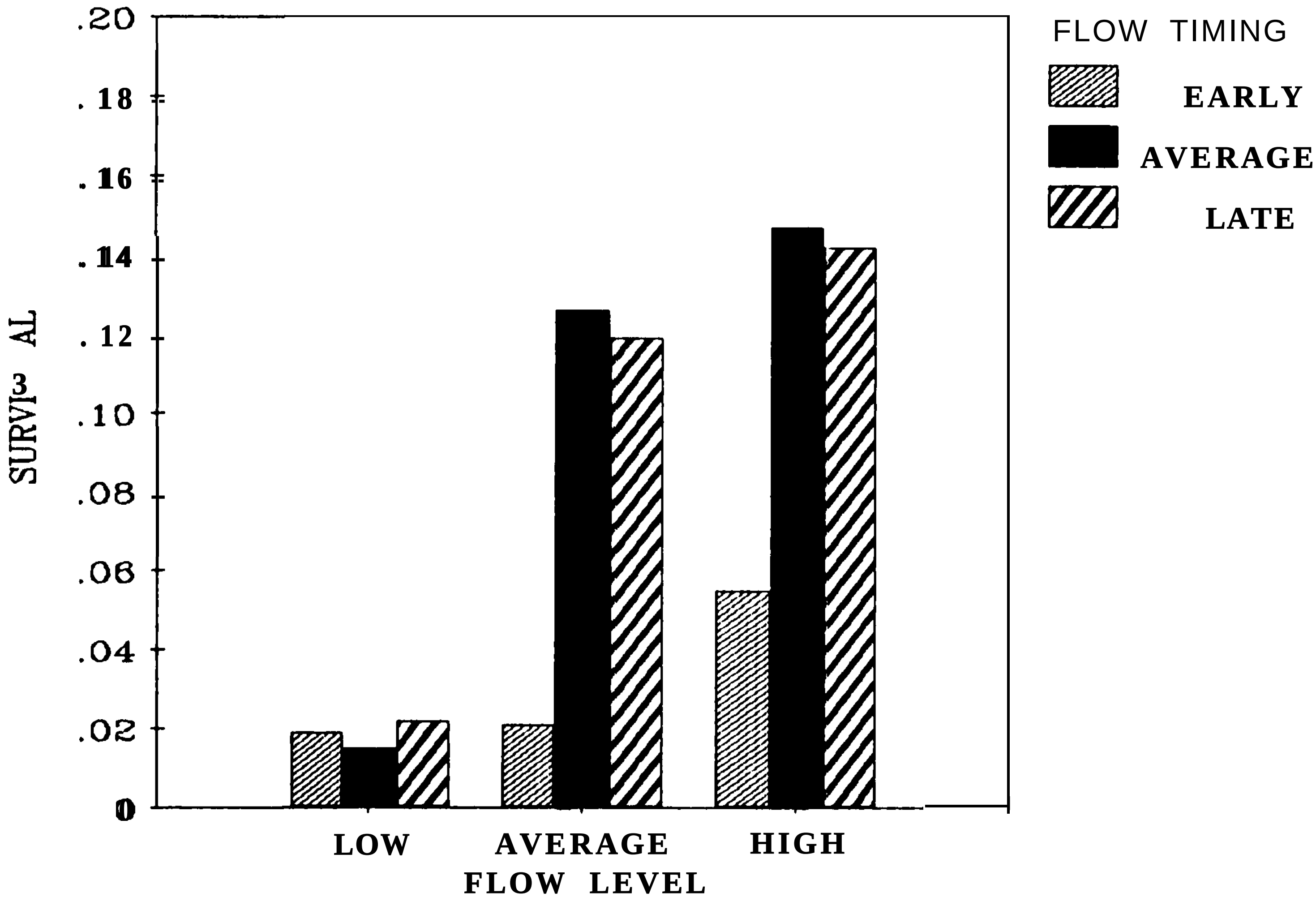
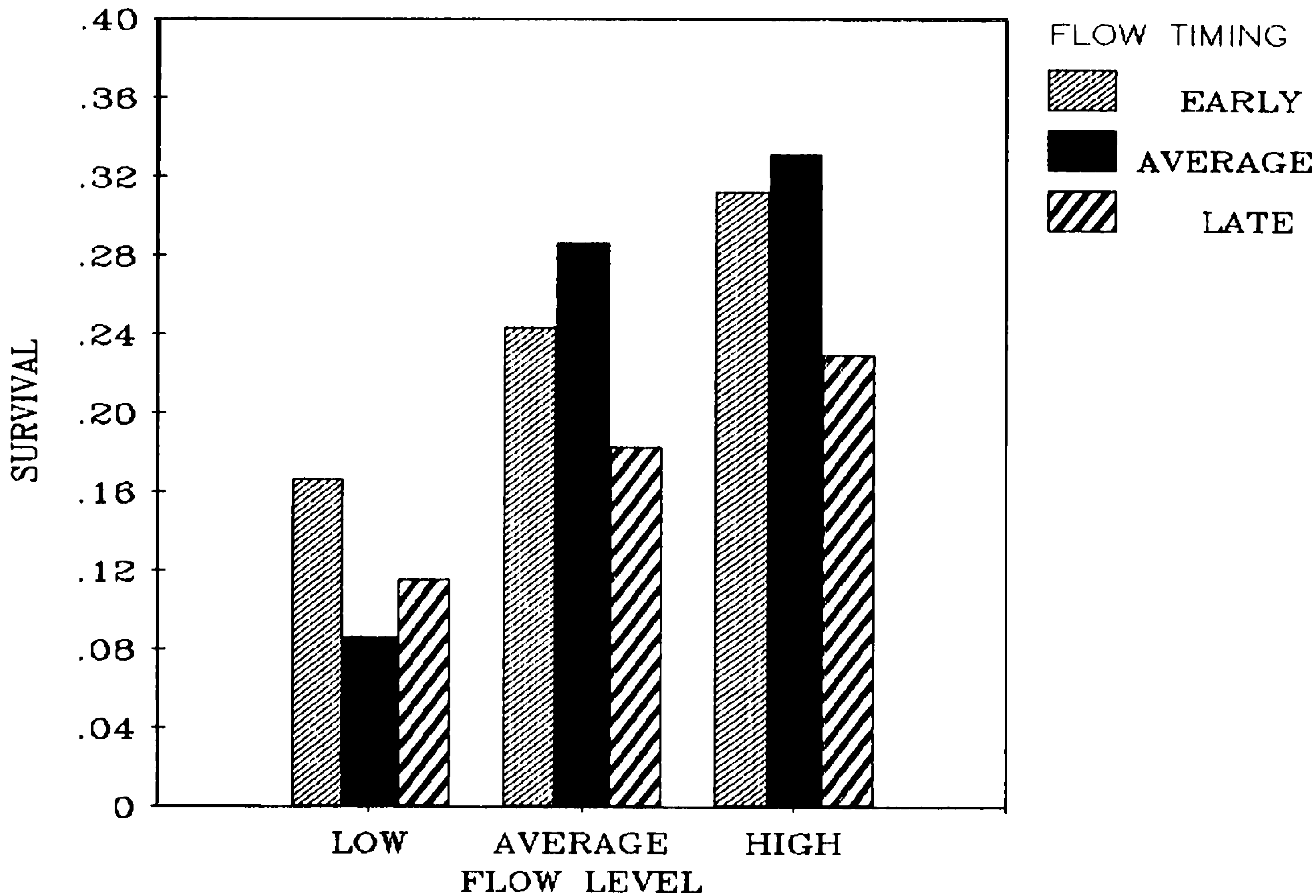


FIGURE 3: SURVIVAL UNDER VARYING WATER CONDITIONS
STEELHEAD: LOWER GRANITE TO BONNEVILLE



The studies above examined the effect of seasonal variation in runoff. Further studies were needed to determine if variations in daily flow levels (within a month), without changing monthly average flow, would affect smolt survival. It is impractical to input into FISHPASS a broad range of flow years as daily average flow values. To overcome this problem FISHPASS uses daily flow values (input as a percent of monthly average flow) from a single year and distributes the monthly average flows supplied for any specific water year. As a result, while monthly average flows may be quite different between two runs made using differing water conditions, the distribution of water within a given month will be the same unless modulator values are changed. The usual practice, followed in this series of analyses, is to use a single modulator pattern for all water conditions. For this reason, it was prudent to examine the effect of the modulator values on smolt survival.

Two sets of modulator values for The Dalles Dam were readily available: 1983 values used by the Corps of Engineers in their spill plan development, and 1985 values used by the Bonneville Power Administration in their Terminal Expansion Environmental Assessment. By chance, the water years and therefore the modulator values, are considerably different.

The 1983 April through August runoff was 121 percent of the 1929 through 1967 average which would have classed the water year as high flow using the criteria described earlier. April through May runoff made up 46.8 percent of April through August runoff, classifying timing as average to late. Later timing was found in 15 of the 39 years used in flow timing and level analysis. The 1985 water year was also somewhat atypical. Flow level was 82 percent of the 1929 through 1967 average, while timing of runoff would be classified as very early. April through ?lay runoff was 53.2 percent of the April through August total. Only 6 of the 39 water years had earlier runoff. Due to the substantial differences between these two water years, they appeared to be suitable as a test for the importance of flow modulator values.

Comparison studies where run using 1942 runoff levels with no transportation and fish from all input sources. Survival of yearling chinook from all locations to below Bonneville Dam was 34.3 percent using 1983 modulator values and 36.7 percent using 1985 modulator values. Survival of subyearling chinook was 37 and 37.1 percent for 1983 and 1985 modulator values, respectively. Steelhead survival was 32.3 percent using 1983 values and 32.0 percent with the 1985 modulator. In comparison to the changes in survival caused by alterations in monthly flow level and timing, these changes seem small. Given this and the fact that day to day changes in flow are determined to a great extent by power system needs and non-power constraints, and are therefore somewhat independent of a hydrologic condition, all further analyses were completed using only the 1983 flow modulator.

Timing of Outmigration and Release of Fish

No analyses of the effect of changes in the timing of outmigration by smolts were initiated. The reason being that the variation in the timing of fish outmigration appears to be incorporated in the analysis of variation in seasonal flow timing. In the seasonal flow analysis, flow timing was varied while outmigration timing was held constant. Studies which varied release timing but held flow timing constant would have produced the same results if the temporal variation were the same. Yore realistic studies may have held hatchery release timing constant while varying slow and wild fish timing. This would correspond to current hatchery release practices which do not time releases to flow conditions and to the widely held belief that wild fish migrations are keyed to flow timing. Such studies would have shown less difference than the seasonal flow timing studies cited above.

Wild fish would have shown no change in survival due to change in seasonal flow timing, while hatchery fish would have been affected to the same extent shown in the flow timing studies. Changes in die1 timing, also, were not examined. The reason is similar. Studies of the effect of changes in project survival targets, which will be discussed later, bracket any possible change in diei distribution. Changes in the die1 distribution affect survival only to the extent that portions of the fish distribution are moved into or away from hours when spill is provided. Since the studies made at a 90 percent spill target provide no spill and the studies made at a 99 percent spill target with 24-hour spill provide a constant and complete spill setting, any change in survival possible through changes in the die1 distribution are bracketed.

Turbine and Reservoir Mortalities

Figure 4 illustrates the survival of yearling chinook from Lower Granite Dam, under 1942 water conditions (used in 1986 spill plan development), to Bonneville Dam (no transport). The first bar of each pair indicates fish arriving at the dam. It is apparent from this figure what more detailed analysis was to confirm. That is, reservoir mortality had a more profound effect on smolt survival than did mortality at the dams. Mortality at dams averaged 5.3 percent while average reservoir mortality was 16.3 percent or 213 percent greater.

To explore this relationship further, turbine and reservoir mortality were varied. Runs were completed with reservoir mortality held constant while turbine mortality was halved and then doubled. These runs were made under no spill condition so that the full effect of turbine mortality would be expressed in survival values. Turbine mortality was then held to MPAC levels while reservoir mortality was halved and then doubled. Finally, studies were run with turbine mortality halved and reservoir mortality doubled, and with turbine mortality doubled while reservoir mortality was halved. Table 5 summarizes these studies in comparison to a study run using MPAC determined criteria (base case). Extreme values were used for turbine and reservoir mortality since these parameters are critical to determinations of survival and there is wide variation among experimentally determined values for turbine and reservoir mortality (6).

FIGURE 4. SMOLT SURVIVAL: 1942 WATER

YEARLING CHINOOK

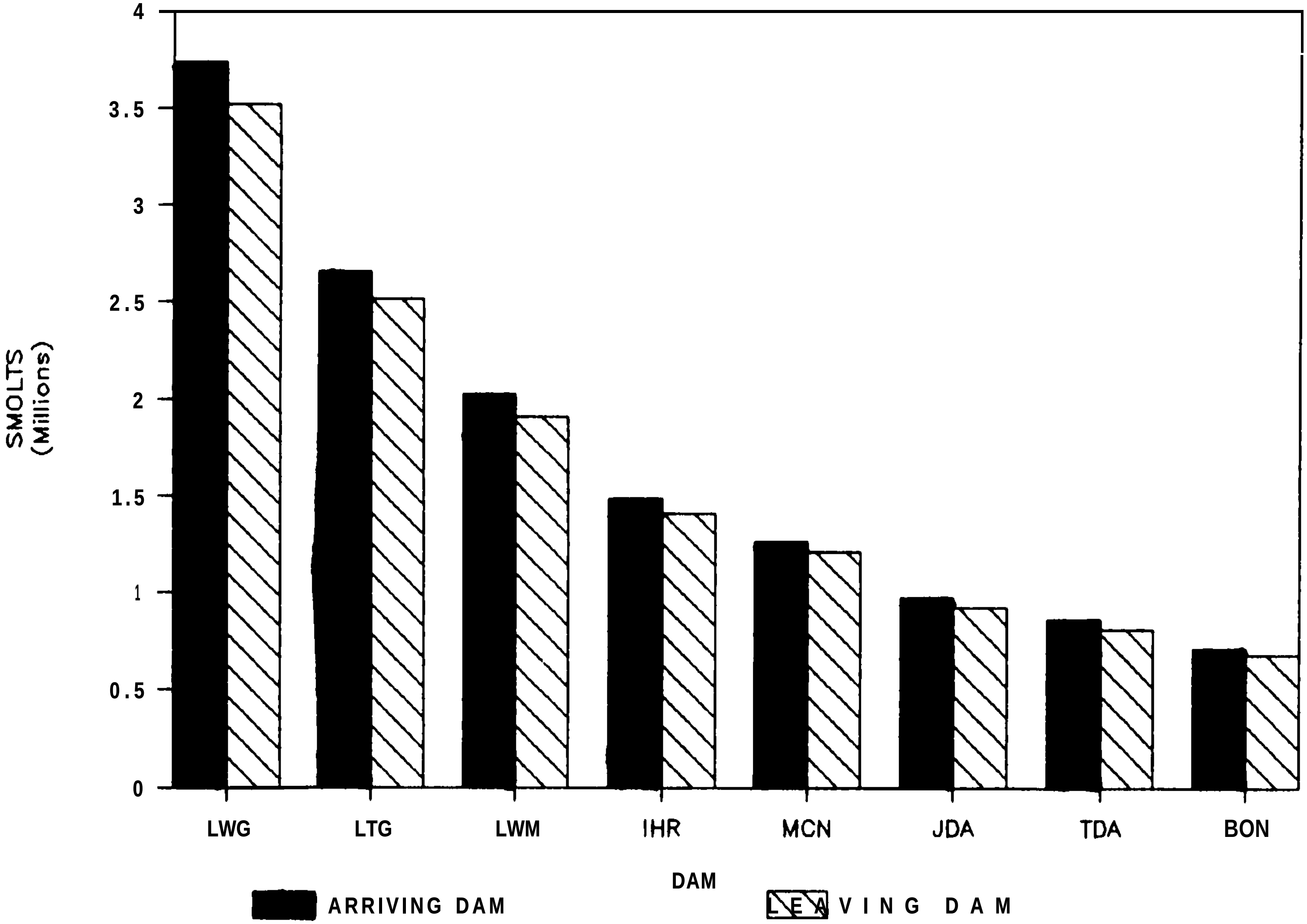


Table 5--SURVIVAL OF SMOLTS FROM LOWER GRANITE DAM UNDER VARING ASSUMPTIONS. WATER YEAR 1942

Yearlina Chinook Survival

Project	Number of Smolts	MPAC Turbine and Reservoir Mortality	Reservoir Mortality Doubled	Reservoir Mortality Halved	Turbine Mortallty Halved	Turbine Mortality Doubled	Turbine Mortality Halved and Reservoir Mortality Doubled	Reservoir Mortality Halved and Turbine Mortality Doubled
Lower Granite	To Oam:	3739.0	3739.0	3739.0	3739.0	3739.0	3739.0	3739.0
	Past Dam:	3518.8	3518.8	3518.8	3602.8	3350.7	3602.8	3350.7
Little Goose	To Dam:	2843.0	2163.8	3197.1	2910.9	2707.2	2215.5	3044.4
	Past Dam:	2690.3	2047.6	3025.5	2811.3	2456.3	2139.7	2'62.3
Lower Monumental	To Dam:	2287.4	1442.3	2805.2	2390.2	2088.4	1507.1	2561.2
	Past Dam:	2158.6	1361.1	2647.3	2305.8	1883.3	1453.9	2309.6
Ice Harbor	To Oam:	1806.4	924.8	2418.6	1929.6	1575.9	987.8	2110.0
	Past Dam:	1714.3	878.0	2294.9	1865.8	1439.1	955.3	1926.2
McNary	To Dam:	1461.6	625.1	2120.1	1590.7	1227.1	680.1	1779.5
	Past Dam:	1397.0	597.7	2026.1	1542.7	1138.5	659.7	1650.6
John Day	To Dam:	1027.8	287.7	1755.4	1134.9	837.8	317.4	1430.2
	Past Dam:	970.4	271.6	1657.3	1095.0	756.3	306.3	1290.9
The Oalles	To Dam:	884.5	227.9	1582.5	998.0	689.3	256.9	1232.7
	Past Dam:	826.7	213.0	1479.1	958.9	608.1	246.9	1087.5
Bonneville	To Dam:	700.4	151.2	1366.6	812.4	515.3	175.2	1004.9
	Past Dam:	673.3	145.4	1313.5	789.8	484.2	170.4	943.9

Subyearling Chinook Survival

Project	Number of Smolts	MPAC Turbine and Reservoir Mortality	Reservoir Mortality Doubled	Reservoir Mortality Halved	Turbine Mortallty Halved	Turbine Mortality Doubled	Turbine Mortality Halved and Reservoir Mortality Doubled	Reservoir Mortality Halved and Turbine Mortality Doubled
Lower Granite	To Dam:	328.0	328.0	328.0	328.0	328.0	328.0	328.0
	Past Dam:	295.9	295.9	295.9	310.6	266.4	310.6	266.4
Little Goose	To Oam:	206.7	116.0	252.5	217.0	186.1	121.8	227.4
	Past Dam:	186.5	104.7	227.8	205.5	151.1	115.4	184.7
Lower Monumental	To Dam:	141.0	57.9	199.2	328.0	114.3	63.8	161.4
	Past Dam:	127.2	52.2	179.7	147.2	92.8	60.4	131.1
Ice Harbor	To Dam:	93.4	27.8	155.4	108.0	68.1	32.2	113.4
	Past Dam:	84.3	25.1	140.3	102.3	55.4	30.5	92.2
McNary	To Dam:	71.8	18.2	129.4	87.3	47.2	22.1	85.0
	Past Dam:	66.1	16.8	119.0	83.3	40.2	21.1	72.3
John Day	To Dam:	47.3	8.1	101.6	59.6	28.8	10.2	61.7
	Past Dam:	42.7	7.3	91.6	56.4	23.4	9.6	50.1
The Dalles	To Dam:	38.5	6.1	86.8	50.9	21.1	8.1	47.5
	Past Dam:	34.7	5.5	78.3	48.2	17.1	7.6	38.6
Bonneville	To Dam:	28.8	3.9	71.4	40.0	14.2	5.4	35.2
	Past Dam:	27.6	3.7	68.2	38.8	13.2	5.3	32.5

Table 5--Continued

Steelhead Trout Survival

Protect		Number of Smolts	MPAC Turbine and Reservoir Mortality	Reservoir Mortality Doubled	Reservoir Mortality Halved	Turbine Mortality Halved	Turbine Mortality Doubled	Turbine Mortality Halved and Reservoir Mortality Doubled	Reservoir Mortality Halved and Turbine Mortality Doubled
Lower Granite	To Dam:		3604.0	3604.0	3604.0	3604.0	3604.0	3604.0	3604.0
	Past Dam:		3485.8	3485.8	3485.8	3512.8	3431.0	3512.8	3431.0
Little Goose	To Dam:		2844.0	2201.0	3181.0	2866.0	2800.0	2218.0	3131.0
	Past Dam:		2714.0	2100.0	3035.0	2778.0	2588.0	2149.0	2894.0
Lower Monumental	To Dam:		2317.0	1497.0	2819.0	2372.0	2210.0	1532.0	2689.0
	Past Dam:		2217.0	1432.0	2697.0	2301.0	2055.0	1487.0	2500.0
Ice Harbor	To Dam:		1861.0	985.0	2466.0	1931.0	1724.0	1022.0	2286.0
	Past Dam:		1778.0	941.0	2356.0	1873.0	1598.0	991.0	2118.0
McNary	To Dam:		1531.0	690.0	2185.0	1613.0	1377.0	726.0	1965.0
	Past Dam:		1482.0	668.0	2116.0	1573.0	1314.0	708.0	1875.0
John Day	To Dam:		1125.0	360.0	1855.0	1193.0	998.0	382.0	1644.0
	Past Dam:		1082.0	347.0	1785.0	1160.0	939.0	371.0	1548.0
The Dalles	To Dam:		995.0	297.0	1711.0	1067.0	864.0	318.0	1484.0
	Past Dam:		936.0	279.0	1610.0	1028.0	774.0	306.0	1330.0
Bonneville	To Dam:		808.0	209.0	1499.0	886.0	668.0	229.0	1238.0
	Past Dam:		778.0	202.0	1443.0	862.0	630.0	223.0	1168.0

Variations in reservoir mortality produced a wide swing in survival of yearling chinook. Halving reservoir mortality nearly doubled surviva! (1.35 times survival in the base case). Doubling reservoir mortality dropped survivai to about one fourth of it's previous value (0.22 times the base case surviva! level). Changes in turbine mortality had a much less impressive effect on survival. Doubling turbine mortality dropped survival to 0.72 of the base value, while halving mortality increased survival to only 1.17 times the base level. When decreases in reservoir mortality were coupled with increases in turbine mortality and vice versa, the result was a dampening of the swing produced by reservoir mortality alone. Decreased reservoir mortality with increased turbine mortality resulted in survival of 1.49 times the base level, a 46 percent reduction in survival from the effect of decreased reservoir mortality alone, but clearly a result in which reservoir mortality had the far more significant role. In the case of a study with increased reservoir mortality and decreased turbine mortality, survival was 0.25 times the base level. When this result was compared to the affect of increased reservoir mortality alone, the increase in survival produced by the decrease in turbine mortality was only 3.7 percent.

Results for subyearling chinook were similar, even though FGE's were substantially lower for this race. Survival past dams averaged 91 percent, while survival between dams was 78 percent (Table 5). The predominance of reservoir mortality as a governing factor is indicated once again by the model runs which doubled reservoir mortality while halving turbine mortality, and those runs which halved reservoir mortality while doubling turbine mortality.

Lower FCE did result in a greater effect by turbine mortality than occurred with yearling chinook. Doubling reservoir mortality while halving turbine mortality reduced survival to 0.19 of the base level as compared to a 1.41 times the base level for reduced turbine mortality aione and 0.13 times the base survival with doubled reservoir mortality alone. Halving reservoir mortality while doubling turbine mortality showed similar predominance of reservoir mortality as a significant determinant of survival. This run produced a survival of 1.18 times the base level. For comparison purposes, halving reservoir mortality alone produced a survival level 2.47 times the base level, while doubling turbine mortality produced a survival level of 0. 48 times the base.

Clearly, reservoir mortality plays a much more significant role than turbine mortality in determining the survival of chinook smolts through the Columbia and Snake River Reservoir systems. This is in large part a result of the assumed existence of bypass at all facilities in these simulations (as recommended by BPA, PNUCC and NPPC). Since only a portion of the fish are affected by turbine mortality, large swings in its level do not translate into large changes in system-wide survival. This is in distinct contrast to reservoir mortality which affects all fish and therefore has a profound influence on results of the modeling.

Closely linked to evaluation of the effect of turbine mortality on modeling analysis is a determination of the impact of changes in target dam survival. FISHPASS allows the user to select a target survival level for passage of fish past a dam. In the series of studies done for this report, the target was set to provide 90 percent survival for all species or races. Since FGE was lowest for subyearling chinook, their survival past dams was lowest and therefore governed spill operations needed at each project. In the 90 percent survival setting no spill was required to obtain the needed survival. In order to evaluate the effect of higher survival levels on modeling results, a series of runs were made at survival levels of 90, 95, 96, and 99 percent. Survival was also evaluated at a 99 percent target level, with spill 24 hours per day, as opposed to the schedule of night hour spill specified in the base input file. The effect of the 99 percent survival target was to provide for 100 percent spill thereby eliminating turbine mortality.

System-wide survival of subyearling chinook from Lower Granite reservoir under the 90 percent survival target was 8.4 percent (Table 6, Figure 5). This increased to 13.1 percent using a 99 percent survival target, with night only spill, and 14.5 percent with 24-hour spill. The maximum absolute survival increase was 6.1 percent with increased spill, a relative increase of 56 percent. Maximum survival increases for yearling chinook and steelhead with increased spill were more moderate, with relative increases of 28 and 17 percent, respectively. These smaller increases in survival are a result of higher FGE's for these fish. The survival increases discussed above must be considered as a maximum possible change since the affect of increased dissolved gasses, and subsequent gas bubble disease are not accounted for in the FISHPASS model as currently used. Since increasing spill also increases dissolved gas, the benefits of spill at some point become self limiting, and total fish survival begins to decrease.

Table 6--COMPARISON OF SYSTEM SMOLT SURVIVAL FOR LOWER GRANITE FISH AT VARIOUS DAM SURVIVAL TARGETS

Yearling Chinook
Project Suvival Target

Project	90%	95%	96%	99% (Night)	99% (24Hrs)
LWG	0.941	0.965	0.970	0.973	0.979
LGS	0.720	0.754	0.761	0.766	0.775
LMN	0.577	0.619	0.628	0.634	0.645
IHR	0.458	0.501	0.509	0.514	0.529
MCN	0.374	0.414	0.422	0.427	0.442
JDA	0.260	0.294	0.301	0.306	0.318
TDA	0.221	0.258	0.266	0.271	0.283
BON	0.180	0.210	0.217	0.220	0.231

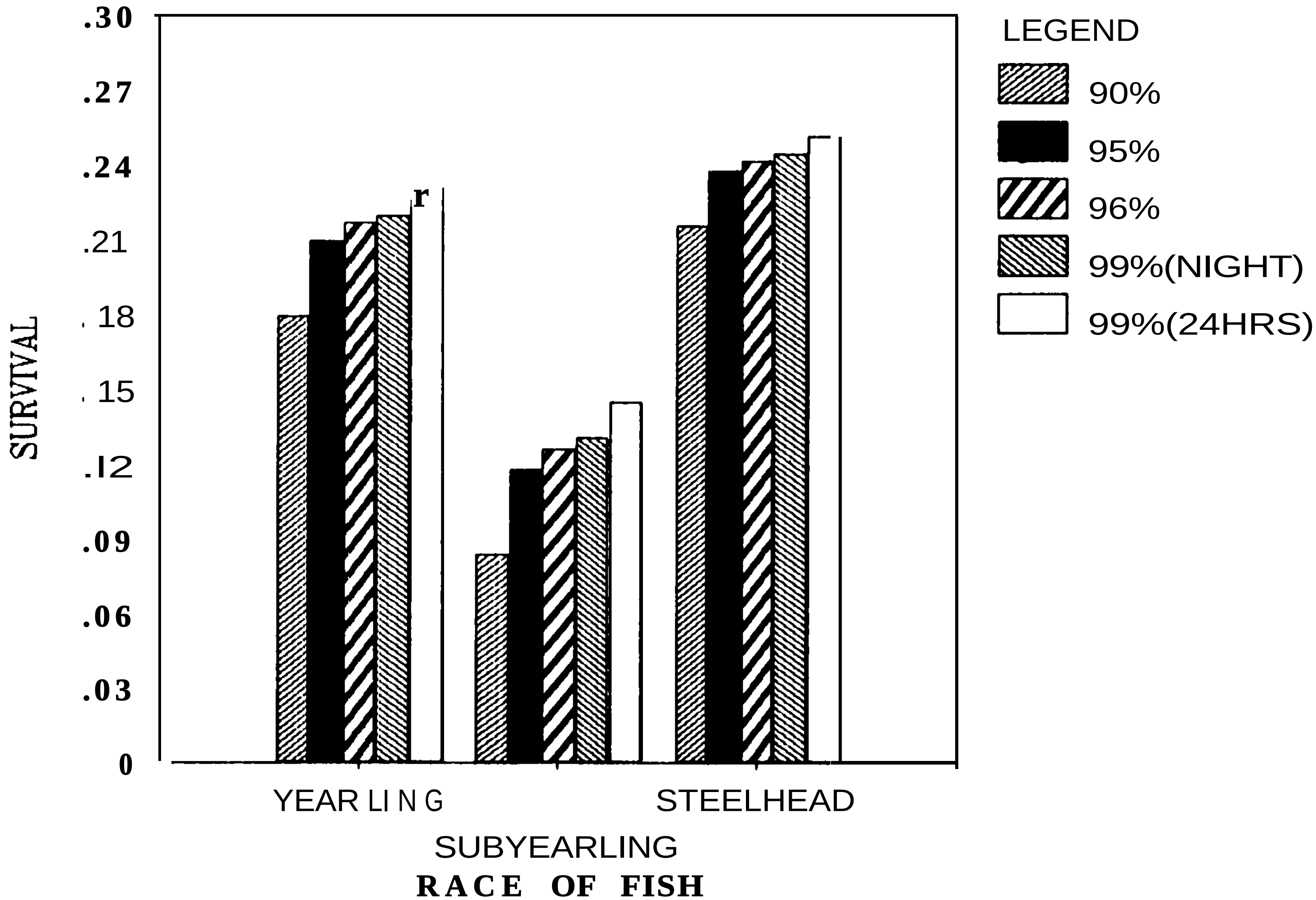
Subyearling Chinook
Project Survival Target

Project	90%	95%	96%	99% (Night)	99% (24Hrs)
LWG	0.902	0.95	0.96	0.966	0.979
LGS	0.569	0.61	0.644	0.675	0.669
LMN	0.388	0.453	0.467	0.476	0.495
IHR	0.257	0.316	0.327	0.333	0.355
MCN	0.202	0.256	0.268	0.275	0.297
JDA	0.13	0.174	0.184	0.19	0.208
TDA	0.106	0.149	0.159	0.165	0.183
BON	0.084	0.118	0.126	0.131	0.145

Steelhead
Project Survival Target

Project	90%	95%	96%	99% (Night)	99% (24Hrs)
LWG	0.967	0.975	0.977	0.978	0.98
LGS	0.753	0.772	0.776	0.778	0.783
LMN	0.615	0.64	0.645	0.648	0.655
IHR	0.493	0.521	0.526	0.528	0.538
MCN	0.411	0.437	0.442	0.445	0.454
JDA	0.3	0.322	0.327	0.33	0.338
TDA	0.26	0.286	0.292	0.294	0.303
BON	0.216	0.238	0.242	0.245	0.252

FIGURE 5. SMOLT SURVIVAL FROM LOWER GRANITE TO BONNEVILLE DAM AT VARIOUS DAM TARGETS



SURVIVAL OF TRANSPORTED FISH

Analysis

Two series of studies were used to evaluate the increase in survival of smolts to Bonneville Dam which might be expected from a transportation program. The first series compares in-river survival, under 1942 water conditions, for fish from various locations to survival of transported fish to below Bonneville Dam. Table 7 compares survival of smolts when no transportation occurs to survival with existing transport (Fish Transportation Oversight Team (FTOT) Plan) and survival with transport at all mainstem Columbia and Snake River Federal dams except Bonneville (full transport). Due to the lack of cumulative dam and reservoir mortality to transported fish, survival of transported fish is substantially higher under the existing transport option than under the no transport condition for fish from all locations affected by transport. Survival of yearling chinook entering above Lower Granite increases by about 4.8 times with existing transport when compared to a no transport condition, while survival of yearling chinook entering the system above Lower Monumental and McNary Dams increases by about 1.9 times. Subyearling chinook survival from above Lower Granite increases by 5.7 times, while survival of subyearling chinook from above Lower Monumental and McNary Dams increases by 1.5 and 1.8 times, respectively (no transport and existing transport). Steelhead survival increases are similar to those of yearling

Table 7--COMPARISON OF SMOLT SURVIVAL TO BELOW BONNEVILLE DAM:

WATER YEAR 1942 BY POOL OF ORIGIN: TRANSPORT V. IN-RIVER MIGRATION

(90% Dam Survival)

		Survival to Below Bonneville Dam		
Fish Enter River In Pool Above	Transportation Occurring	Yearling Chinook	Subyearling Chinook	Steelhead
Lower Granite Dam	No	0.172	0.089	0.212
Lower Granite Dam	Existing	0.821	0.508	0.904
Lower Granite Dam	Full	0.836	0.605	0.908
Lower Monumental Dam	No	0.235	0.234	0.249
Lower Monumental Dam	Existing	0.443	0.361	0.498
Lower Monumental Dam	Full	0.769	0.675	0.811
McNary Dam	No	0.442	0.363	0.503
McNary Dam	Existing	0.846	0.663	0.891
McNary Dam	Full	0.883	0.717	0.923
John Day Dam	No	0.624	0.469	0.526
John Day Dam	Existing	0.624	0.469	0.526
John Day Dam	Full	0.863	0.607	0.732
The Dalles Dam	No	0.686	0.558	0.743
The Dalles Dam	Existing	0.686	0.558	0.743
The Dalles Dam	Full	0.812	0.660	0.849
All Dams Listed Above	No	0.343	0.370	0.323
All Dams Listed Above	Existing	0.819	0.617	0.851
All Dams Listed Above	Full	0.857	0.694	0.893

chinook at 4.26 for Lower Granite fish and 2.0 and 1.8 for Lower Monumental and McNary fish, respectively. Steelhead survival increases are similar to those of yearling chinook at 4.26 for Lower Granite fish and 2.0 and 1.8 for Lower Monumental and McNary fish, respectively.

When full transport is simulated, survival increases are greatest for fish from Lower Monumental pool. Yearling and subyearling chinook survival increased by 1.7 times, while steelhead survival was 1.6 times higher than under existing transport conditions. Survival increases for fish from other projects were lower with minimal increases at Lower Granite (1.0, 1.2, 1.0 times), and McNary (1.0, 1.1, 1.0 times). Survival increases for fish from The Dalles (1.2, 1.1, 1.1 times) and John Day (1.4, 1.3, 1.4 times) were intermediate.

From a system-wide perspective, with fish from all input sources considered, survival increased by addition of existing transport to 2.4, 1.7, and 2.6 times for yearling chinook, subyearling chinook, and steelhead, respectively, as compared to a non-transport situation. When full transport is compared to existing transport, survival increases by another 1.1 times for all fish. These levels of increase reflect the distribution of stocks within the basin as modeled by the input file. Greater system-wide benefits accrue to species which are distributed higher in the watershed than those found mainly in the lower river system.

A second series of studies was run to examine the change in survival for fish stocks from specific locations which resulted from incremental addition of transport facilities. These analyses were run under low and high water conditions with average runoff timing as described in the introduction to this paper. The flow comparisons were believed to be important due to the large variation in survival shown by the sensitivity analysis.

So existing production, or plans for future production, of fish which would enter the system in the reservoirs above Little Goose or Ice Harbor Dams were identified. For that reason, this series of simulations did not examine the effect of additional transport on fish from these sources.

Simulation of transport at Lower Monumental Dam did little to assist survival of fish entering the system above Lower Granite Dam. The maximum increase noted was for subyearling chinook under high water conditions where survival increased by 3.9 percent to 62 percent (Table 8). Survival of fish entering the system in the reservoir above Lower Monumental Dam was increased substantially by simulation of transport at Lower Monumental Dam. At the maximum, steelhead survival under low flow conditions increased by 33.0 percent. The minimum increase was 16.8 percent for subyearling chinook under high flow conditions. No other stocks were affected by transport at Lower Monumental Dam.

Table S--SURVIVAL OF SMOLTS UNDER SEVERAL TRANSPORT ALTERNATIVES

Survival of Yearling Chinook to Below Bonneville Dam Under Several TransDort Alternatives

TransDort At	Flow Level	Fish Enter System Above This Dam LWG	LWM	HCN	JDA	TDA	Flow Level	Fish Enter System Above This Dam LWG	LWM	MCN	JDA	TDA
LWG.LTG.MCN	LOW	0.803	0.365	0.842	0.452	0.517	High	0.809	0.510	0.540	0.672	0.760
LWG.LTG.MCN LHN	LOW	0.815	0.676	NA	NA	NA	High	0.832	0.710	NA	NA	NA
LWG.LTG.MCN LHN.IHR	LOW	0.817	0.713	NA	NA	NA	High	0.837	0.760	NA	NA	NA
LWG.LTG.MCN LMN,IHN.JDA	LOW	0.817	0.714	0.873	0.772	NA	High	0.838	0.768	0.859	0.819	NA
LWG.LTG.MCN LMN.IHR.JDA.TOA	LOW	0.817	0.714	0.877	0.809	0.703	High	0.839	0.770	0.865	0.850	0.833

Survival of Subyearling Chinook to Below Bonneville Dam Under Several Transport Alternatives

TransDort At	Flow Level	Fish Enter System Above This Dam LWG	LWM	MCN	JDA	TDA	Flow Level	Fish Enter System Above This Dam LWG	LWM	MCN	JDA	TDA
LWG,LTG.MCN	LOW	0.514	0.206	0.573	0.219	0.436	High	0.581	0.421	0.717	0.579	0.598
LWG.LTG.MCN LMN	LOW	0.547	0.443	NA	NA	NA	High	0.620	0.589	NA	NA	NA
LWG.LTG.MCN LMN.IHR	Low	0.555	0.513	NA	NA	NA	High	0.631	0.639	NA	NA	NA
LWG.LTG.MCN LMN.IHR.JDA	LOW	0.556	0.518	0.615	0.348	NA	High	0.634	0.655	0.712	0.668	NA
LWG.LTG.MCN LMN.IHR.JDA.TDA	LOW	0.556	0.519	0.626	0.383	0.569	High	0.635	0.661	0.724	0.691	0.687

Survival of Steelhead to Below Bonneville Dam Under Several TransDort AlternativeS

Transport At	Flow Level	Fish Enter System Above This Dam LWG	LWM	MCN	JDA	TDA	Flow Level	Fish Enter System Above This Oam LWG	LWM	HCN	JDA	TDA
LWG.LTG.MCN	LOW	0.898	0.415	0.878	0.353	0.604	High	0.873	0.621	0.868	0.591	0.722
LWG.LTG.MCN LHN	LOW	0.901	0.745	NA	NA	NA	High	0.886	0.865	NA	NA	NA
LWG.LTG,MCN LHN,IHR	LOW	0.901	0.766	NA	NA	NA	High	0.889	0.883	NA	NA	NA
LWG.LTG.MCN LMN.IHR.JDA	LOW	0.901	0.766	0.907	0.600	NA	High	0.890	0.886	0.880	0.750	NA
LWG.LTG.MCN LMN.IHR.JDA.TDA	LOW	0.901	0.766	0.909	0.614	0.776	High	0.890	0.886	0.885	0.765	0.864

Addition of transport at Ice Harbor had almost no effect on survival of fish from above Lower Granite Dam and moderate impact on survival of fish from the Lower Monumental reservoir. The maximum survival increase for Lower Granite fish was 1.1 percent for subyearling chinook under high flow. The maximum increase for Lower Monumental fish was 7.0 percent for subyearling chinook under low flow conditions. The average survival increased by 4.1 percent across fish stocks and flow conditions.

Addition of transport at John Day Dam had little effect on survival of stocks from Lower Granite (maximum 0.3 percent increase) or Lower Monumental (maximum 1.6 percent increase) reservoirs. Stocks entering the system in the reservoir above McNary Dam (including mid-Columbia stocks) obtained limited benefit from addition of transport at John Day Dam. The maximum increase in survival, due to addition of transport at John Day, occurred with low flow for subyearling chinook (4.2 percent). Fish entering the John Day reservoir received the greatest benefit from transport at John Day. Yearling chinook survival increased by 32 percent under low flow and 14.7 percent under high flow. Steelhead survival increased by 24.7 percent under low flow and 15.9 percent under high flow. Survival of subyearling chinook was affected more modestly at 12.9 percent and 8.9 percent under low and high flows, respectively.

Addition of transport at The Dalles had little or no effect upon survival of smolts originating in the Snake River. The maximum increase of 0.6 percent occurred for subyearling chinook from Lower Monumental reservoir under high flow. Likewise, fish entering the system from McNary reservoir (including mid-Columbia stocks) obtained little benefit from addition of transport at The Dalles. A maximum increase in survival of 2.3 percent was obtained for subyearling chinook under high flow conditions. John Day fish obtained high benefit. A maximum increase in survival of 3.7 percent occurred for yearling chinook under low flow conditions. The average change in survival was an increase of 2.58 percent. Fish from The Dalles reservoir benefitted most from transport at The Dalles. Yearling chinook migrating under low flow received the greatest benefit (18.6 percent increase in survival). The average increase in survival was 12.42 percent.

Summary of Transport Studies

The results of this analysis indicate that substantial benefits accrue to stocks entering the reservoir just above a new transport project with some benefit also being provided to stocks from the next upstream reservoir. Benefits to stocks more distantly removed are minimal, especially if intervening dams have transport facilities. Transport at Lower Monumental would provide substantial benefit only to stocks entering at that reservoir (Lyon's Ferry hatchery and Tucannon fish). Addition of transport at Ice Harbor would provide benefit only to those stocks also receiving benefit from a facility at Lower Monumental Dam. The magnitude of those benefits would be minor.

Transport at John Day would provide greatest benefits to John Day and Umatilla River stocks, as well as to hatchery releases occurring in the reservoir, such as the release of fall chinook in the Rock Creek backwater area. Migrants from McNary reservoir including mid-Columbia stocks would benefit, to a lesser degree, from transport at this facility. Transport at The Dalles would provide maximum benefit to migrants from the Deschutes River while providing lesser benefit to stocks described under John Day transport. Of the four sites under discussion, transport at Ice Harbor is the least attractive due to the narrow range of fish receiving benefit, and the lack of stocks entering directly into its reservoir (stocks which would stand to gain the most from added transport). While a broader range of fish would benefit from transport at The Dalles than at John Day, the addition of greater travel distance of mid-Columbia, McNary and John Day Reservoir fish outweighs (at least numerically) the benefit to fish from The Dalles' reservoir. The significantly higher in-river survival of fish from the Dalles reservoir, as compared to mid-Columbia fish also is important in preferential siting of transport at John Day rather than The Dalles. Since both John Day and Lower Monumental provide for substantial increases in survival to below Bonneville Dam for specific fish stocks, selection of either site as a preferred location for transport would depend on the relative priority of increasing the survival of the stocks in question.

Survival of Transported Fish Over the Life Cycle

This analysis has, due to the limitation of the FISHPASS model, dealt only with survival of smolts from a headwater dam to below Bonneville Dam. As stated earlier, this ignores much of the variability involved in the absolute numbers and final ratio of outmigrants to returning adults.

Other factors which may affect the validity of an analysis such as this, and a discussion of their relevance, is thus necessary. Survival to the first dam has not been considered. For example, an analysis using 1986 PIT tag data (7) for tagged Dworshak hatchery steelhead and yearling chinook, and a FISHPASS simulation of the actual 1986 migration yielded the following results. Assuming FGE's at Lower Granite dam of 0.50 for yearling Chinook and 0.74 for steelhead (3), survival of Dworshak hatchery fish to Lower Granite dam was 52 percent for steelhead and 38 percent for yearling chinook. Mortality before encountering the first dam is high and is not considered by FISHPASS. This is not a problem for the current analysis, however, since transported and non-transported fish should suffer the same mortality.

The analysis has considered survival from Lower Granite to Bonneville Dam, for in-river migrating fish. For Dwowrshak fish (included to allow comparison to other figures in this section) survival was estimated to be 24 percent for yearling chinook and 26 percent for steelhead. To this point 13.5 percent of steelhead and 9.1 percent of the yearling chinook which left the hatchery remain.

Mortality below Bonneville Dam has likewise been ignored. If return rates for fish surviving to below Bonneville dam are similar to those for transported fish from the period 1975-1979, only about 2.81 percent of steelhead and 0.47 percent of spring chinook should return as adults [calculated from (2)]. This indicates a substantial mortality after leaving Bonneville Dam which is not taken into account by the FISHPASS model and which can affect the results presented. For this reason, the remainder of this section will deal with this portion of the life cycle and data available to estimate associated mortality.

Post Transport Survival

For yearling chinook, the substantial numerical advantage created by transportation, in terms of survival of smolts to Bonneville Dam, cannot be statistically demonstrated in terms of returning adults (8) indicating that lower Columbia River and ocean survival may differ for transported and non-transported fish. It is also possible, however, that survival does not differ and that problems with experimental design mask the benefits of transport in the results of transport experiments. These alternatives will now be considered.

Reliability of Transport Studies

A portion of the inability to detect differences among returning transported and non-transported adults lies in problems with the design of experiments which are intended to evaluate transportation. Evaluation of transportation has traditionally been carried out as a comparison of transport to in-river migration, with the latter serving as "controls". The difficulties with this design center around the variability inherent within each group and the low number of fish which were available for both experimental and control groups.

In terms of variability within groups, the problems associated with use of in-river migrants as controls are most apparent. These fish are not static controls. For example, the number of dams, amount of spill at each dam, flow present during migration, fish health, predator abundance, food availability and other variables act on these fish to produce within group year to year variation in abundance. Transported fish are also not homogeneous in their survival from year to year. They are affected by changes in the transport system and fish health. Both groups are strongly influenced by year to year variability in ocean condition. Importantly, ocean survival may vary independently for transport and control fish producing what has been called differential survival or adult return ratio.

Low numbers of smolts available for tagging in both experimental and control situations have plagued transportation experiments. This has resulted in returning adult numbers so low that no effect, regardless of impact, would have been detectable. This has particularly been a problem for spring chinook where the percent of tagged transported fish returning is lower than for steelhead.

An additional difficulty has plagued transportation research in that not all control fish remain controls. Many of these fish (again unfortunately a variable percentage of the total) are picked up by transport facilities lower in the system and are, unknown to the experimenter, given the differential effect of transport. Attempts to minimize the effect of transport of control fish have served to further complicate the design and factors which may be acting on the control group. For example, control fish captured at Lower Granite Dam have been transported to below Little Goose Dam to avoid their transport at this facility. In the process, fish have been subjected to conditions which true in-river migrants never encounter.

Differential Mortality

Even with the problems which plague transportation research, results may indicate that some factor influences transported fish in a way which increases their post Bonneville mortality to above that of non-transported fish (9). This potential "differential mortality" will now be considered using yearling chinook as an example.

Asswnming that a differential mortality does exist, it may be explained by at least two hypotheses. The first hypothesis would assume a source of mortality exists which is a direct result of the transport process. Examples of such a source of differential mortality would be transport induced stress (10), or disease disseminated through close contact of diverse fish stocks during transport. Another example would suppose a source of mortality associated with a positive density dependent factor. For example, if food supply is a limiting factor for survival below Bonneville Dam, the large numbers and high density of fish released by transport could produce an adverse effect on survival.

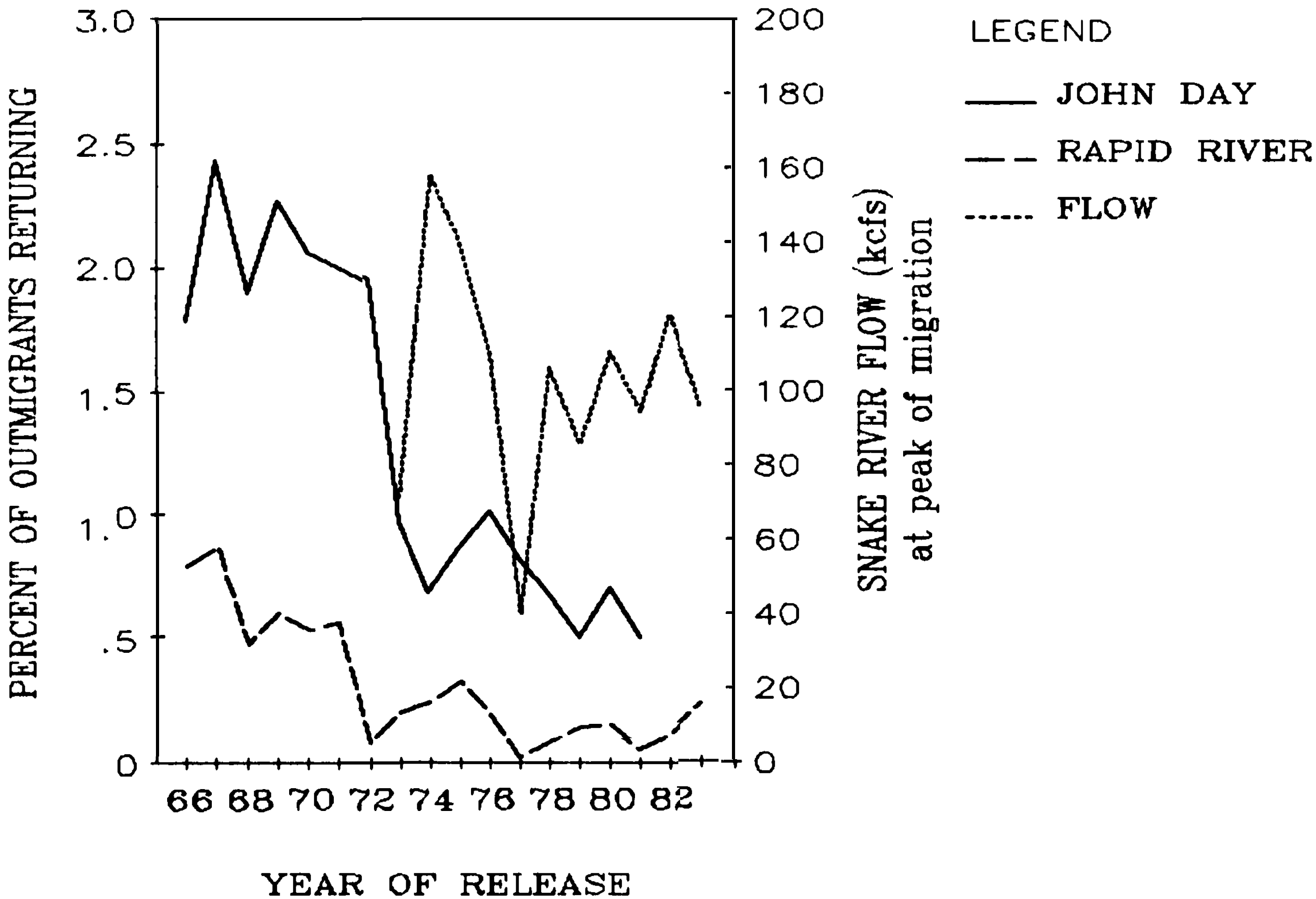
The other hypothesis assumes that a very high percentage of fish will die regardless of the method by which they are passed downstream. This hypothesis assumes that weaker fish would be preferentially killed by the rigors of in-river migration. The result would be a group of in-river migrants which would be stronger and better able to survive post-migratory life than the mixture of weak and strong fish delivered by transportation. While both of these hypotheses would result in "differential mortality", they have very different implications.

The former is very much a problem to be dealt with by improved in-river migration and transport. Better transport regimes, intended to reduce the factor which produces the differential mortality, would result in much improved adult return rates. Improvement of in-river migration conditions, in lieu of transport, should also result in direct increases in adult return rate if an assumption is made that the in-river journey kills weak and healthy fish at comparable rates. However, if the in-river migration kills weak fish in disproportionate numbers, efforts to increase in-river or transport survival will be much less successful. Leaker fish are saved but will be lost during the post-migratory period. The result is a differential mortality which will affect any group of fish for which survival during migration is increased. If this possibility holds true, primary emphasis for increasing return rates for depressed stocks may lie in improving fish health and/or in disease control rather than in improvements in downstream migrant survival. For purposes of this report, the important distinction between these possibilities lies in the role of transportation. If a true differential mortality exists for transported fish, then transport (until the source of differential mortality is identified and reduced) may not be a suitable alternative, at least for yearling chinook stocks. If differential mortality is a result of fish condition or health, transport may well be an efficient and reliable means for providing adequate downstream migrant survival for all stocks. Unfortunately, it is impossible with existing information to know which, if either, of these rationale explains a potential differential in mortality to transported fish. Some interesting inferences may, however, be made. First, if the source of differential mortality were due to poor fish quality, there should be a greater differential mortality in those stocks where return rate is lowest. This would be due to the higher intrinsic mortality rate for these stocks, as is the case. Steelhead, which return at higher rates (2.81 percent for transport groups from Lower Granite Dam in 1975-1979 excluding 1977 [calculated from (2)1 show better transport to in-river survival rates than spring chinook (0.47 percent for transport groups from Lower Granite Dam, 1975-1979 excluding 1977 [calculated from (2)] which return at lower rates. Second, if fish in poor health were differentially killed during downstream migration, the rate of disease should decrease among surviving fish. For instance, spring chinook from five upper Columbia River hatcheries averaged a 94 percent incidence of bacterial kidney disease (BKD) at their time of release, during 1984. By the time these fish reached the Columbia River estuary, incidence of BKD was only 3.2 percent (11). Clearly, the fish with EKD had suffered a higher mortality than other fish. Finally, if poor fish quality were the source of differential mortality, the transport to non-transport adult return ratio should be reduced from the smolt in-river to transport ratio observed at Bonneville Dam, but should be consistently positive. This would occur since the majority of fish "saved" through transport are of poor quality and will die in any case, but some are genuinely healthy fish saved from turbine mortality and other sources of mortality. These fish will survive to return as adults and boost the transport to non-transport return ratio. This is a sequence which generally fits the observed data. Yearling chinook transport experiments from Lower Granite dam to Bonneville Dam have yielded the following transport to control ratios: nine were positive, two were one-to-one, one was negative, and four were tests where insufficient returns existed to estimate a transport to control ratio. When all transport experiments with yearling chinook are considered, fifteen have been positive, two were one-to-one, five were negative, and six have resulted in insufficient returns to calculate a ratio.

While these points do not prove that differential mortality is a result of poor fish quality, they certainly make this possibility worth considering. When evaluating the role of factors outside downstream migration in the decline and continued poor condition of Columbia River spring chinook stocks, one additional point worth considering is a steep downward slide in return rates during the mid-1970's. This trend was reported by Park (2) in a comparison of stocks from the Snake and mid-Columbia Rivers. He reported a post-1975 decline in return rates of spring chinook which appears to be independent of conditions for downstream migrants. This trend may clearly be seen in Figure 6 which shows return rates per outmigrant from two broadly dissimilar stocks of spring chinook.

Rapid River hatchery return rates (12) clearly show a post 1971 decline in return rates. A similar post 1972 decline in return rates for John Day wild spring chinook (13) is also seen, even though these stocks have little in common. The John Day stock's decline did not occur in association with the construction of John Day dam which was in place by 1968 and fully on line by the time of the 1971 outmigration. No other construction affected this stock. In contrast, the Rapid River stock was affected by nearly continuous system expansion across the late 1960's and early to mid-1970's. Hatchery practices would have affected the Rapid River but not the John Day stock while instream rearing conditions would affect the John Day but not the Rapid River. A positive correlation of number of fish to flow at time of outmigration is seen for Rapid River fish ($r^2 = 0.38$, $p = 0.044$, df = 9) but not for John Day fish ($r^2 = 0.0015$, $p = 0.921$, df = 7). Therefore, annual changes in water condition do not seem to account for the drop in return rate seen in both stocks. While no identified in-river factor is associated with the observed decline in the two stocks' return rates, it is clear that some drastic change has occurred. The correlation between variation in return

FIGURE 6. COMPARISON OF ADULT RETURNS FOR TWO STOCKS OF SPRING CHINOOK

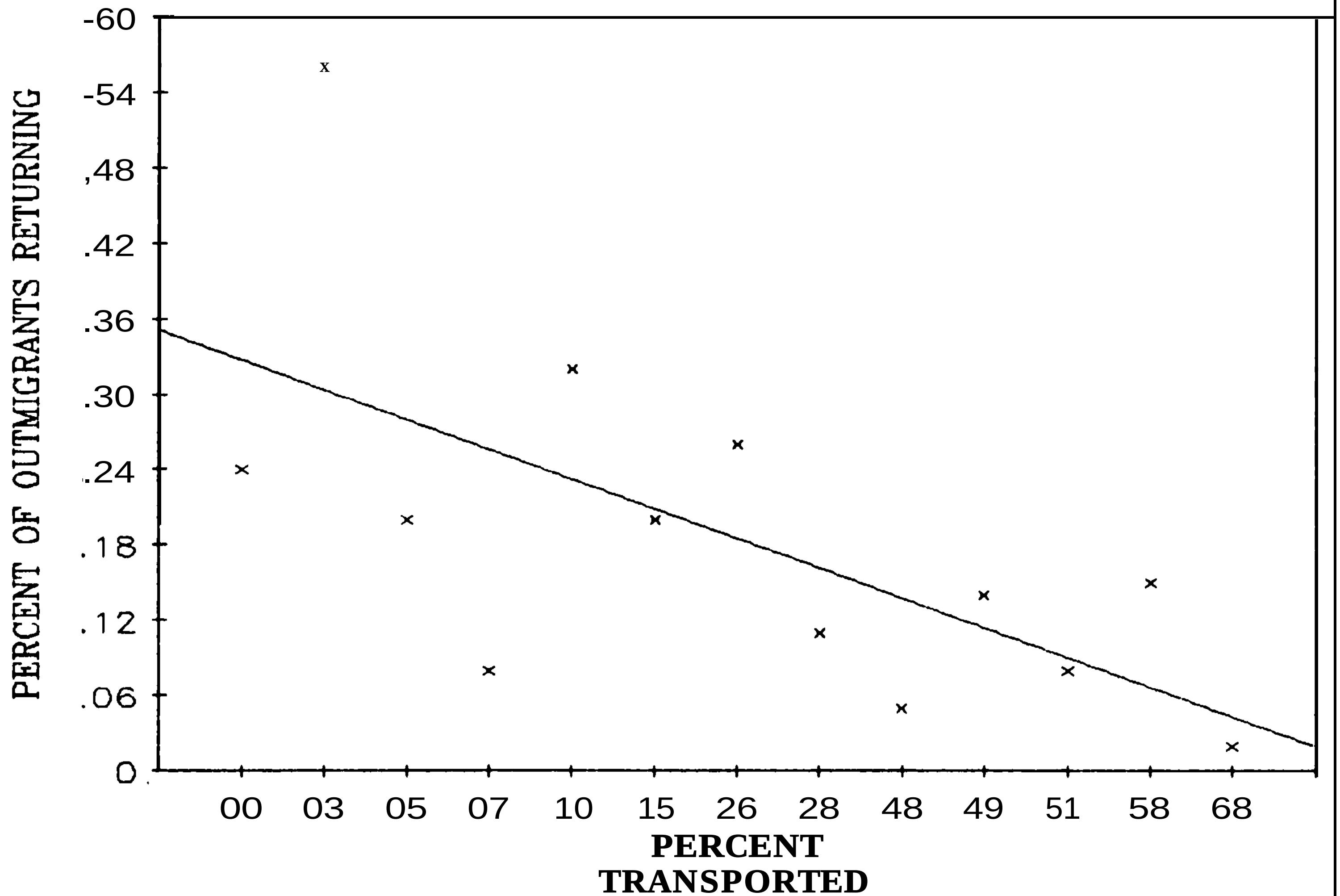


rates for the two stocks is good (r^2 = 0.66, p = 0.0002, df = 14) indicating that the same factor or series of factors may have caused much of the variation in both stocks. Again, this information does not provide evidence for or against differential mortality caused by transport but does point out the existence of overriding factors which greatly influence overall stock survival, and perhaps limit overall adult return regardless of the relative success or failure of downstream migration.

From another perspective, some information exists which supports a differential mortality produced by transport. If the return rate to Rapid River hatchery is compared to the percent of fish transported, the r^2 value is 0.40 for 1971-1983 (p = 0.0086, df = 7) (Figure 7). This observation is interesting as it is not a consequence of two variables which are positively correlated with time (year v. percent transported r^2 = .02, p = 0.683, df = 7, and year v. Rapid River Hatchery returns r^2 = .03, p = 0.649, df = 7). As the percent of yearling chinook transported increased through 1980, the adult return rate to Bonneville dam showed a general decline. Decreased transport in 1982 and 1983 was associated with higher adult return rate. While the relationship is far from perfect, it may suggest an association between transport and declining returns.

The purpose of this section has been to discuss the limits of any analysis which only examines survival of smolts to below Bonneville Dam, the area of direct hydroelectric impact. It is just as important, however, that the reader recognize that comparisons with existing data of returning adults (even though increase in that measure is the ultimate goal of any enhancement) is just as

FIGURE 7. RETURNS TO RAPID RIVER HATCHERY COMPARED TO EXTENT OF TRANSPORTATION



invalid. A potential failure of transported fish to survive the rigors of ocean life, and return at rates as high as those potentially obtained for in-river migrants, may not be due to failure of transport as a management tool. Rather, it may point to unidentified problems in salmonid stocks, particularly spring chinook. Unfortunately, use of adult return data to evaluate the success of transport is no better than use of survival to Bonneville. Until research tools improve sufficiently to allow a full understanding of the sources of mortality to salmonids from the beginning of migration until their return as adults, no measure of the effectiveness will be of unquestionable value.

CONCLUSION

The results of the modeling analysis performed for this paper indicate that transportation could substantially increase the survival of smolts to Bonneville Dam. This is true even with FGE increased to levels as high as can reasonably be expected and with good instream flow conditions. The addition of new transport facilities at Lower Monumental and John Day Dams could substantially increase the survival of specific stocks of fish. Further expansion of transport to include Ice Harbor and The Dalles Dams would produce only minimal increases in survival to below Bonneville Dam and may not be an adequate indicator of the effectiveness of transport. However, the alternative measure (survival to adult) may incorporate the effect of additional sources of mortality which mask the true effectiveness of transport.

Research findings currently available are unable to address the success of the transport program in a meaningful manner. Research currently being conducted offers little promise to do more than extend the number of years for which inconclusive data are available. Additional research, using more fish and newer tagging techniques, is needed to apportion the sources of mortality to salmonids and measure the true benefit of the transportation program. The passive integrated transponder (PIT) tag shows promise as a tool to determine the pickup rate for control fish at downstream transport facilities alleviating the need for short haul transport and handling of controls. This would reduce the number of confounding factors by producing more reliable data while using fewer fish. If adequate numbers of control and experimental fish are made available, the worth of transport may finally be determined. If, however, the current program of transporting a portion of the yearling chinook while allowing the rest to migrate in-river and providing inadequate fish for definitive experiments continues, we will remain unsure of the causes of fluctuations in outmigrant-to-adult survival rate. If that rate improves, we will remain uncertain of the cause and will be afraid to take any action with regard to transport, harvest, or river flow operations for fear or returning to a state of declining return rates. On the other hand, if the decline in return rates continues we will only watch helplessly uncertain of which action to take (more transport or more in-river passage) to improve the situation.

It appears that a commitment to either transport or in-river migration is superior to the current mixed mode provided that, which ever path is taken, adequate research is included to be reasonably certain that we understand the reasons for changes which result from the action. Given the overriding impact of reservoir mortality and the current inability to alter this mortality more than fractionally, transport would appear to be worth assessing. It is unlikely that a short term commitment to full transport could produce disaster, given the fairly small absolute difference in rates of return indicated by currently available data. A short term commitment to adaptive management can prevent a long term commitment to uncertainty which is likely to cause the further deterioration in fish runs that we seek to avoid.

The decision to expand transport to other facilities is not one that need be made now. The addition of transport at Lower Monumental, Ice Harbor, or The Dalles is dependent on the construction of bypass/transport facilities at these projects. As long as the design of prospective bypass facilities allows for the addition of transport at a later time, no irrevocable decision need be made immediately. Retrofit of bypass at John Day is possible at any time. The real decision which needs to be made is the commitment to a definitive study of the merits of transport, including the resources needed to produce meaningful results.

At the same time, it appears possible that the major problem resulting in low return rates for yearling chinook lies not in the downstream migration of these fish, but rather in their health or condition as they begin migration. Efforts to evaluate this possibility should be given priority status equal to efforts to improve downstream migrant survival.

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APPENDIX I: SUMMARY TABLES

Table Al. Flow timing at Lower Granite Dam.

Year	Proportion of Avg. Flow	Flow Class	April-May Proportion of Flow	June-August Proportion of Flow	Runoff Timing
1929	0.762	Low	0.503	0.497	
1930	0.683	Low	0.587	0.413	Avg
1931	0.559	Low	0.651	0.349	
1932	1.042	Avg	0.570	0.430	
1933	0.999	Avg	0.397	0.603	Late
1934	0.618	Low	0.710	0.290	Early
1935	0.722	Low	0.543	0.457	
1936	0.962	Avg	0.667	0.333	Early
1937	0.649	Low	0.557	0.443	
1938	1.094		0.560	0.440	
1939	0.710	Low	0.673	0.327	
1940	0.782	Low	0.650	0.350	
1941	0.714	Low	0.490	0.510	Late
1942	0.915		0.537	0.463	
1943	1.482	High	0.538	0.462	
1944	0.722	Low	0.503	0.497	
1945	0.873		0.467	0.533	
1946	1.048	Avg	0.618	0.382	
1947	1.054	High	0.595	0.405	
1948	1.414	High	0.507	0.493	
1949	1.114		0.651	0.349	
1950	1.258	High	0.468	0.532	
1951	1.158		0.599	0.401	
1952	1.457	High	0.669	0.331	Early
1953	1.137		0.411	0.589	
1954	1.046	Avg	0.529	0.471	Avg
1955	0.973	Avg	0.428	0.572	
1956	1.440	High	0.615	0.385	
1957	1.315	High	0.594	0.406	
1958	1.175		0.617	0.383	
1959	0.986	Avg	0.465	0.535	
1960	0.928		0.528	0.472	
1961	0.822		0.509	0.491	
1962	0.990	Avg	0.543	0.457	
1963	0.930		0.479	0.521	
1964	1.229	High	0.423	0.577	Late
1965	1.504	High	0.519	0.481	Avg
1966	0.699	Low	0.599	0.401	
1967	1.035	Avg	0.407	0.593	

Table A2. Flow timing at The Dalles.

Year	Proportion of Avg. Flow	Flow Class	April-May Proportion of Flow	June-August Proportion of Flow	Runoff Timing
1929	0.682	Low	0.501	0.499	
1930	0.639	Low	0.498	0.502	
1931	0.639	Low	0.514	0.486	
1932	1.026	Avg	0.545	0.455	
1933	1.150		0.350	0.650	
1934	1.023	Avg	0.566	0.434	Early
1935	0.881		0.430	0.570	
1936	0.883		0.566	0.434	
1937	0.670	Low	0.507	0.493	
1938	1.003	Avg	0.509	0.491	
1939	0.828		0.523	0.477	
1940	0.788	Low	0.526	0.474	Early
1941	0.724	Low	0.503	0.497	
1942	0.894		0.451	0.549	
1943	1.220	High	0.455	0.545	Avg
1944	0.673	Low	0.500	0.500	Avg
1945	0.785	Low	0.451	0.549	Late
1946	1.069		0.518	0.482	
1947	0.986	Avg	0.539	0.461	
1948	1.440	High	0.386	0.614	
1949	0.999	Avg	0.543	0.457	
1950	1.288	High	0.363	0.637	Late
1951	1.257	High	0.521	0.479	Early
1952	1.140		0.569	0.431	
1953	1.020	Avg	0.384	0.616	
1954	1.257	High	0.405	0.595	
1955	1.014	Avg	0.349	0.651	Late
1956	1.478	High	0.513	0.487	
1957	1.120		0.506	0.494	
1958	1.023	Avg	0.528	0.472	
1959	1.186		0.426	0.574	
1960	0.972	Avg	0.474	0.526	Avg
1961	1.057	High	0.462	0.538	
1962	0.948		0.482	0.518	
1963	0.852		0.447	0.553	
1964	1.133		0.364	0.636	
1965	1.266	High'	0.472	0.528	
1966	0.845		0.487	0.513	
1967	1.142		0.356	0.644	

APPESDIX II: CHANGING FISHPASS

Description of Current Model

The FISHPASS model was developed by the U.S. Army Corps of Engineer's North Pacific Division as a tool to investigate the alternative programs for spill of water used to increase the survival of migrating juvenile salmon and steelhead. FISHPASS was programmed in an iterative development method. That is, a base model was developed and improvements, as well as additions and deletions of structure, were made by addition rather than by redesign and restructure of the model. As a result of this process, the model is difficult to understand and is somewhat limited in its versatility. I see three major problems with the model which could be remedied by a rewriting of FISHPASS in a structured form using the existing model as a framework.

Specific problems with the model include the following. The model may, as occurred twice during this effort, override specified input variables without warning the user that this has occurred. The output generated is incorrect, but if changes are minor, the user may be unaware that the model has not performed as directed. Both of the problems which I mention above were the result of an attempt to use the model in a broader context than that for which it was designed. In one case, the model failed to recognize the simulation of a bypass system at Ice Harbor and The Dalles, and in the other, it would not allow simulation of transport facilities at projects other than those at which transport is currently operating. In each case the input file variables and documentation led me to believe that FISHPASS could model the condition desired and no error messages were generated to tell the user that the model had done anything other than the input specified. A second problem also related to the difficulties just described is that the model is designed to simulate current conditions. In designing the model, current conditions such as partial screening at John Day Dam, are built into the model rather than specified as part of the input data. This limits the models flexibility in modeling alternatives to system bypass development. Finally, FISHPASS is cumbersome to use. All input is fed into a somewhat cryptic and often redundant input file. The user is not able, without significant experience with the model, to determine which variable or variables should be used to do tasks such as preventing passage spill at specific projects, transporting early in the season and spilling later, or installing a transport system while disabling a sluiceway.

Suggested Changes

As a result of the difficulties described above, I would suggest a rewriting of the FISHPASS program. I believe the following goals should guide the programming effort: (1) the model should be flexible, allowing the user to make any change in design or operation of the system as simply as possible;

(2) the model should be user friendly designed to allow people familiar with the fishery and operational problems but with little computer expertise to easily use the model for their needs; (3) the model should be well documented with built in error checking allowing the user to understand why the model produces a certain solution; and (4) the model should be compact allowing it to be installed on a personal computer since these are more widely available than mainframe computers.

Specifically, I would suggest that the design include the following features: The basic algorithm should be the same for each project, with differences such as sluiceways or transport facilities handled in an input file. There should be several input files divided by subject such as project operations, fish input, fish survival criteria, and water year. This would allow for less redundant data storage when modeling across a series of conditions. The input should be built in to error check the input file and warn the user of missing or out of bounds data.

No model will be perfect or meet all needs. However, I see the need to redesign the FISHPASS model to make it more flexible, easier to use, and more reliable. While no one is satisfied relying on model output for decision making, it is clear that the complexity for fish passage decision making demands a tool that will assimilate all available data and predict the possible outcomes of any decision. If no single, satisfactory tool is available to all concerned parties, a multitude of tools is likely to emerge adding another layer of complexity to a situation which could hardly benefit from such an outcome.

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